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ABSTRACT

This report discusses the development and implementation of computer-related teaching materials for undergraduate physics courses. A list of the computer dialogs developed, with a short description of each, is included. The types of dialog are: (1) development of an interactive proof, (2) assistance in problem solving, (3) diagnosing and filling in limitations in the student's mathematical background, (4) simulations, and (5) quizzes containing minimum performance standards. Techniques used in the dissemination of project materials are described, along with future applications and studies to be conducted in this project, supported by the National Science Foundation. (TS)

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PHYSICS COMPUTER DEVELOPMENT PROJECT - Progress Report

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February 19, 1971

This report discusses the development of computer related teaching materials for undergraduate physics courses, using the computer in a variety of ways to enhance the teaching of physics. The project is supported by the National Science Foundation.

Software Development

When the project began, the University of California, Irvine, was undergoing a computer revolution. During the first summer no facilities were available. In fall an XDS SIGMA 7 (used in this project) was installed for the student terminal system, along with a DEC PDP-10 for research. The SIGMA 7 had a student-usable timesharing system with BASIC and FORTRAN for computation; although I do not consider these the best choices for beginning physics students,[1] they were deemed sufficient. Hence, software developments

concentrated on facilities for dialog material, for which little was available.

Several design considerations influenced us. Pedagogical considerations of how students learn, should, we feel, always take precedence over hardware or software factors. We wanted authors to be reasonably free of the details of how their programs would be entered on the machine; the teacher needs to know what is possible with computers but need not have detailed knowledge of the computer or its software.

Noah Sherman and Alfred Bork initially planned on paper, two dialogs to see what software would be useful.

Another programming consideration was not to rule out anything the machine was able to do; the software should provide the teacher access to any facilities available in a modern computer. Flexibility was also a keynote; as new teaching needs developed we hoped to change the facilities in an easy and dynamic way.

Our primary job was producing physics teaching material, so we were satisfied with "quick and dirty" ways which led more directly to classroom-usable materials. Work in using computers in education had often degenrated into development of software little used for teaching purposes.

A minor design consideration was that we hoped to run our programs with large numbers of students for testing and improvement. It would be convenient to use an interpretive language in developing

dialogs, but for running programs with many students efficient run time code was desirable. Our trade-off was to spend more computer time in the developmental phase and less computer time in the production-usage phase.

Given these design criteria, we worked primarily in Assembly language, with programs primarily composed of macro (procedure) calls. The macros, for efficiency, usually establish linkages to library subroutines. The addition of new macros and subroutines is simple and represents the main way in which the system has grown as needs develop. As with any Assembly program, the program can contain Assembly instructions and can call FORTRAN subroutines; we use FORTRAN where much calculation is required.

We wanted the facilities to be usable by secretaries; the great bulk of our dialogs are entered from terminals by secretaries, directly from the author's flowcharts. The secretary is the principal "coder", and the facilities must be oriented to her needs and background. Thus most of the macros have simple English names, rather than abbreviations, and most have a limited number of simple arguments.

The macros are described in several user oriented documents, available to those working on dialog material. This documentation exists at several levels, depending on the needs of users.

Dialog Development

Before this project the principle investigator had notes[2,3,4,5] in which the computer was being used extensively in a computational mode within the beginning physics course, in the first two quarters (mechanics and waves). This material has been used with science and engineering majors at Irvine for three years, beginning 1968-1969, with revisions each year based on student feedback. The approach to mechanics is non-conventional; the computer allows students to proceed immediately to using the Laws of Motion as differential equations. The course has been described elsewhere.[3]

An early decision was to develop dialog and simulation material related to the already existing material using the computational mode, so a principal thrust has been the production of dialogs in the mechanics and waves parts for the course for science and engineering majors.

We believe that we have the most extensive and widely tested physics dialog material available. Our efforts to contact others with physics material with the possibility of using them on our system, have not been very fruitful. In addition to the material developed locally, we have several dialogs on our system that were designed by Noah Sherman's group at the Lawrence Hall of Science at the University of California, Berkeley. A list of dialogs follows.

PCDP DIALOGUES AVAILABLE OR UNDER DEVELOPMENT

CONSER

LEVEL: PHYSICS 5A OR 5B
STATUS: TESTED WITH PHYSICS 5A STUDENTS IN 1969-197Ø, REWRITTEN
AUTHORS: NOAH SHERMAN, UNIVERSITY OF MICHIGAN, AND ALFRED BORK.

THIS DIALOGUE GUIDES THE STUDENT TO DERIVE CONSERVATION OF ENERGY FOR A ONE DIMENSIONAL MECHANICAL SYSTEM STARTING FROM THE LAWS OF MOTION. IT REQUIRES SOME KNOWLEDGE OF CALCULUS

TWO VERSIONS ARE CURRENTLY IN USE, CHOSEN RANDOMLY.

*

ELECTRIC

LEVEL: PHYSICS3
STATUS: TESTED WITH A FEW STUDENTS IN 1969-197Ø
AUTHOR: KENNETH W. FORD, UNIVERSITY OF MASSACHUSETTS, BOSTON

TEN SIMPLE QUESTIONS WHICH CHECK A STUDENT'S KNOWLEDGE OF FORCE BETWEEN CHARGED PARTICLES AND ON CHARGED PARTICLES IN ELECTRIC FIELDS. PROVIDES GUIDANCE TO THE STUDENT WHO IS HAVING PROBLEMS IN ADDITION TO GIVING HIM CORRECT ANSWERS. CALLED A ''THRESHOLD QUIZ,'' IT IS INTENDED AS ONE OF A SERIES TO INSURE A MINIMAL STANDARD OF PERFORMANCE FOR ALL STUDENTS IN A CLASS.

*

COMPTON2

LEVEL: PHYSICS 5B-INTRODUCTORY RELATIVITY
STATUS: USED WITH PHYSICS 5B STUDENTS 1969-197Ø REWRITTEN
AUTHOR: MARK MONROE

ASSISTANCE FOR A STUDENT WHO HAS DIFFICULTY IN WORKING PROBLEM 7Ø IN ''SPACETIME PHYSICS'', TAYLOR-WHEELER. THE PROBLEM CONCERNS THE RELATIVISTIC COMPTON EFFECT. ASSUMES FAMILIARITY WITH THE PROBLEM.

*

TRANSFOR

LEVEL: PHYSICS 5A
STATUS: USED WITH A FEW STUDENTS 1969-197Ø, REWRITTEN.
AUTHOR: LYN CALERDINE

COORDINATE TRANSFORMATIONS BETWEEN TWO CARTESIAN SYSTEMS--TRANSLATIONS, REFLECTIONS, GALILEAN TRANSFORMATION.

*

DOPPLER

LEVEL: PHYSICS 5B-INTRODUCTORY RELATIVITY
STATUS: UNTESTED
AUTHORS: ALFRED BORK AND MARK MONROE

OFFERS ASSISTANCE TO STUDENTS WHO HAVE DIFFICULTY WITH PROBLEM 75 IN ''SPACETIME PHYSICS'', TAYLOR-WHEELER. THE PROBLEM CONCERNS THE RELATIVISTIC DOPPLER EFFECT. REVIEWS LORENTZ TRANSFORMATION FOR ENERGY-MOMENTUM. ASSUMES FAMILIARITY WITH THE PROBLEM.

*

COUPOSC

LEVEL: PHYSICS 5B

STATUS: UNTESTED
AUTHOR: CHARLES MUNCH
INTRODUCTION TO COUPLED SYSTEMS AND CHARACTERISTIC FREQUENCIES USING TWO MASSES CONNECTED WITH THREE EQUAL SPRINGS ON AN AIRTRACK. ATTEMPTS TO LET THE STUDENT TAKE BIG STEPS, BUT IF HE CANNOT DO SO IT GIVES HIM ASSISTANCE. APPROXIMATE TIME: TWO HOURS.

*

VIOLIN
LEVEL: PHYSICS 58
STATUS: UNTESTED
AUTHOR: ALFRED BORK
STANDING WAVES ON A STRING WITH FIXED ENDS. ASSUMES SOME KNOWLEDGE OF COUPLED SYSTEMS, AS GIVEN IN DIALOGUE COUPOSC. ALSO ASSUMES ELEMENTARY ACQUAINTANCE WITH THE ONE-DIMENSIONAL CLASSICAL WAVE EQUATION.

*

FORCES
LEVEL: HIGH SCHOOL OR BEGINNING COLLEGE
STATUS: UNTESTED
AUTHOR: ALFRED BORK
CALCULATION OF THE RATIO OF ELECTRICAL TO GRAVITATIONAL FORCE BETWEEN TWO ELECTRONS.

*

COMPNUM
LEVEL: HIGH SCHOOL OR BEGINNING COLLEGE
STATUS: UNTESTED
AUTHORS: ALFRED BORK AND LYN CALERDINE
CHECKS THE STUDENT'S KNOWLEDGE OF COMPLEX ARITHMETIC AND EXPONENTIAL FUNCTIONS OF COMPLEX ARGUMENT. OFFERS ASSISTANCE WHERE THAT KNOWLEDGE IS WEAK.

*

VECTOR2
LEVEL: HIGH SCHOOL OR PHYSICS3
STATUS: UNTESTED
AUTHOR: NOAH SHERMAN, UNIVERSITY OF MICHIGAN
QUESTIONS ABOUT VECTORS, RELATED TO THE PROJECT PHYSICS COURSE. TEMPLATE STRUCTURE.

*

M3M2
LEVEL: HIGH SCHOOL OR PHYSICS 3
STATUS: UNTESTED
AUTHOR: NOAH SHERMAN, UNIVERSITY OF MICHIGAN
ANALYSIS OF A SYSTEM OF TWO MASSES ON A FRICTIONLESS SURFACE, CONNECTED TO A THIRD MASS OVER A PULLY. RELATED TO PROJECT PHYSICS COURSE. TEMPLATE STRUCTURE.

*

WAV
LEVEL: HIGH SCHOOL OR PHYSICS 3
STATUS: UNTESTED
AUTHOR: NOAH SHERMAN, UNIVERSITY OF MICHIGAN
QUESTIONS ABOUT WAVES. RELATED TO PROJECT PHYSICS COURSE. TEMPLATE STRUCTURE.

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FOURIER
    LEVEL: UNDERGRADUATE
    STATUS: UNDER DEVELOPMENT
    AUTHOR: RANON UDKOFF
    CHECKS KNOWLEDGE OF FOURIER SERIES, ASKING STUDENT TO
ENTER THE COEFFICIENTS OF THE FOURIER SERIES FOR SEVERAL
FUNCTIONS. ALLOWS CHOICE OF AXIS, AND PROVIDES A DATA BASE
OF INFORMATION RELATED TO FOURIER SERIES.
*
HARMONIC
    LEVEL: INTRODUCTORY PHYSICS
    STATUS: UNTESTED
    AUTHOR: THOMAS STARK, CALIFORNIA STATE COLLEGE,
              FULLERTON, AND JOE ZELIGS
    ANALYTIC SOLUTIONS TO THE SIMPLE AND DAMPED HARMONIC
OSCILLATOR: SOLUTIONS TO THE DIFFERENTIAL EQUATIONS, EXAMPLES
OF OVER, UNDER AND CRITICALLY DAMPED HARMONIC MOTION.
ASSUMES A KNOWLEDGE OF COMPLEX NUMBERS (SEE COMPNUM).
*
LEM1
    LEVEL: HIGH SCHOOL OR BEGINNING PHYSICS
    STATUS: UNTESTED
    AUTHOR: STEVE DERENZO, UNIVERSITY OF CALIFORNIA, BERKELEY

    A SIMULATED MOON LANDING, WITH PRELIMINARY QUESTIONS ON THE

KINEMATICS OF MOTION AT CONSTANT ACCELERATION.
*
NEIL
    LEVEL: HIGH SCHOOL OR BEGINNING PHYSICS
    STATUS: UNTESTED
    AUTHOR: STEVE DERENZO, UNIVERSITY OF CALIFORNIA,BERKELEY

    THE MOON LANDING ONLY, FROM LEM1.
*
ROPEGAME
    LEVEL: PHYSICS 58
    STATUS: UNTESTED
    AUTHORS: JOHN ROBSON, UNIVERSITY OF ARIZONA
              AND ALFRED BORK
    SIMULATES A PLANE WAVE IN A ROPE. FIRST SUPPLIES A
STUDENT WITH MEASUREMENTS IN POSITIONS AND TIMES HE SUGGESTS,
AND THEN ALLOWS THE STUDENT TO COMPLETE INFORMATION ABOUT THE
ROPE PARTIALLY SUPPLIED BY THE COMPUTER.
*
KEPLER2
    LEVEL: HIGH SCHOOL OR BEGINNING PHYSICS
    STATUS: UNTEST
    AUTHOR: NOAH SHERMAN (UNIVERSITY OF MICHIGAN)
    QUESTIONS ON KEPLER'S THREE LAWS OF MOTION. REVIEWS
THE GEOMETRY OF CONIC SECTIONS.
*
MAGNETIC
    LEVEL: PHYSICS 3
    STATUS: UNTESTED
    AUTHOR: KENNETH W. FORD. UNIVERSITY OF MASSACHU-
              SETTS, BOSTON
    TWENTY SIMPLE QUESTIONS WHICH CHECK A STUDENT'S KNOWLEDGE
OF MAGNETIC FIELDS. PROVIDES GUIDANCE TO THE STUDENT WHO IS

HAVING PROBLEMS IN ADDITION TO GIVING HIM CORRECT ANSWERS.
CALLED A ''THRESHOLD QUIZ,'7 IT IS INTENDED AS ONE OF A
SERIES TO INSURE A MINIMAL STANDARD OF PERFORMANCE FOR ALL
STUDENTS IN A CLASS.
*
ROTATE
    LEVEL: BEGINNING PHYSICS
    STATUS: UNDER DEVELOPMENT, UNTESTED
    AUTHOR: LYN CALERDINE
    HELPS THE STUDENT TO DERIVE THE TRANSFORMATION EQUATIONS
FOR ORTHOGONAL ROTATIONS.
*
PLANET
    LEVEL: BEGINNING OR INTERMEDIATE PHYSICS
    STATUS: UNTESTED
    AUTHOR: MARK MONROE
    THE KEPLER PROBLEM FOR ONE BODY, BY EXACT METHODS.
DEMANDS REASONABLE KNOWLEDGE OF CALCULUS.
*
ENDING

Considerable discussion took place during the first summer about what types of dialogs would be most appropriate. We believe that we do not now know enough about how to use computers in education to plan an entirely dialog-driven course, so we picked a few areas and types of dialogs in which computer usage would give some unique leverage in teaching, in a way difficult to obtain with other teaching material.

What happens in physics, and other science courses, particularly at the elementary level? In the conventional lecture/text-oriented course, at least two major components or activities occupy much of the time. The first, in class and in the text, is the development of important results: the logical derivation, with increasingly sophisticated mathematical tools, of new results from old results. Thus, Newton's Laws are the basis of mechanics; conservation laws and the motions of particular systems are derived from F = ma. The teacher wants the student not only to learn these things, but also to learn to derive such results.

The typical lecture derivation, a prepared "speech", is a passive experience for most students. Motivational aspects, including the issue of how to originate such a proof, are often lost. The typical student response is that he could follow the proof, but could not have generated it. This is usually realistic; the original development of this result was probably longer and more indirect than the one presented on the board. If the student reads this material in a text the situation is similar: Again the experience tends to be passive, with the student's role, if any, being to fill in missing details.

A computer dialog can make a proof a more dynamic and interactive experience for the student, doing a better job of teaching the result and teaching the art of problem solving. Our first dialog was the proof of energy conservation in one dimension starting from the Laws of Motion. This dialog was used in 1969-1970, was rewritten based on massive student feedback and used again in 1970-1971. It is a nontrivial task for the student to generate such a proof and we do not expect many to succeed without assistance and hints. But he can take some steps on his own, and he can receive remedial math help if needed. The dialog introduces the students to a full one-dimensional definition of potential energy, unlikely to have been encountered in high school because calculus was not used; it is described in a paper.[6]

Results in using this dialog, judged from student questionnaires and performance on exams, was encouraging; students asked for more dialog material, so we continued to produce other interactive proofs. In the list one might, in particular, note PHYSICS1 (the dialog just described), TRANSFOR, ROTATE, COUPOSC, and VIOLIN. All these either derive important results, or introduce critical concepts. All are in use in 1970-1971 and will, hopefully, be rewritten using student feedback.

A second major component of student performance in a physics course is the working of problems, and a second type of dialog is associated with a particular problem. From the student point of view the course is defined by the problems he works; typically the course has a steady

load of problems. In our course we use nontrivial problems, with few simple plug-in problems. Hence the student is often confronted with a difficult task he cannot immediately accomplish. He can resort to consulting more knowledgeable friends or the faculty, or to reading in the texts or references. But these assistance mechanisms may not be available, particularly if troubles occur late at night. Delays of hours or days can occur before he gets assistance, and he can get more and more behind in the course.

We felt that problem assistance was a fertile field for the student-computer dialog. Many students are stuck at the same places or with the same conceptual difficulties. If the teacher writes a problem-assistance dialog after helping students with the problem, he knows the likely student difficulties and can develop a dialog carefully tailored to student needs.

Two dialogs, COMPTON and DOPPLER, are based on problems in Taylor-Wheeler, Spacetime Physics, tough problems for many students, involving important issues of physics. We have discussed further very different types of problem assistance, but no active work has gone ahead in that direction.

A third type of dialog useful in teaching beginning science courses is oriented toward diagnosing and filling in limitations in the students' mathematical background. If most of the class is familiar with complex numbers, but a number of the students in the class have no background or have forgotten the material, the teacher cannot present a detailed lecture. These needy students can be referred to books or given

special help, but their needs differ, and it is difficult to find time to work individually with each. The dialog on complex numbers, COMPNUM, deals with this situation; the student faces a series of increasingly difficult tasks concerning complex numbers. If he can accomplish each he is quickly finished. However, if he has trouble with a small problem in complex numbers, then he is given some assistance in whatever is necessary to accomplish that particular task, and given the chance to try the problem again. This variety of dialog is not new, but it is useful in allowing a course to be more flexible.

A fourth type of dialog, straining the use of the term dialog, is often referred to as a simulation, although a pure simulation might not be usable in a teaching situation. Of the two current simulations NEIL, a Lunar Landing simulation, was developed by the Berkeley group at the Lawrence Hall of Science lead by Noah Sherman. The second, ROPEGAME, developed by John Robson and Alfred Bork, involves a wave in a rope; it tries to get students to discover empirically through a measurement-like facility the traveling pattern idea, and the mathematical representation of this idea. Student success must come in performance; no explicit discussion of the (x - vt) dependence of the wave occurs, but the questions asked require that such knowledge be on hand.

Our experience with these simulations is puzzling. Both of these simulations are stimulating and highly motivational, so simulation is a success in arousing student interest. However, if one also wants a simulation in teaching some aspect of physics it becomes much more difficult plan and write such materials. Our wave simulation has

gone through six versions, trying to make the learning experience more effective. We are still not sure that the majority of the students will learn what we expect them to, and so are anxiously waiting our full trial.

The Lunar Landing is certainly exciting. Vast numbers of students, (perhaps 1000) at UCI have used this program year, including many not associated with any physics class, even though it has never been required. However, there is some question as to how much physics people learn. The situation requires only knowledge about motion at constant acceleration. But what one often sees is a student paying no attention at all to the physics, but pursuing it as an adventure! So motivationally the dialog rates high, but in terms of what it teaches it is harder to evaluate. It does stimulate some students to study the problem analytically, so for a few it may lead to learning physics.

A fifth type of dialog developed somewhat outside the lines already described, was intended for a different course, the introductory course taken primarily by biology majors, by Kenneth Ford, University of Massachusetts, Boston. The concept is that of a series of "threshhold" quizes given throughout the course, minimal performance standards that the student must pass. Two of these dialogs were written, ELECTRIC and MAGQUIZ. Although these are simple dialogs compared to others in the project, they have an interactive flavor, and we have also found them very useful for demonstration purposes with students and teachers at the high school level. We have not exhausted all our dialogs, but we have looked at the main types.

Mechanism for Dialog Preparation

The project gave thought to the question of how dialogs can best be prepared. Many of the people we would like to interest in preparing such materials have little interest in computer details. Furthermore these competant teachers are often not expert typists, and quickly become tired of the vast amounts of typing often involved in dialog preparation, much of it text material to be displayed to the student. We want to capitalize on a combination of physics and teaching interests, even if computer interests are not involved.

The prospective author first decides what he wants to do, the kind of dialog he wants to write, the subject matter covered, etc. This is often the largest block of faculty time; some of our dialogs have involved many days in this planning stage before any material is put on paper. In the interactive proof dialog, the author may want to study the different ways that the result can be proved, keeping in mind the abilities of the students using the dialog.

An author can work conveniently with a simplified flowchart; he writes on the paper in a diagram-like structure the sequences for the student. We show him examples of flowcharts and dialogs, including dialogs he can run at the terminal. We try not to restrict him not because we find that individuals have different preferences. Thus, although most of our authors prefer to work mostly with lines with arrows going here and there, some like to work with the equivalent of labels directly within the dialog.

The teacher's material, the flowchart, goes to the secretary, who types the source file for the program at a terminal. We train secretaries, again through simple examples, to go from the flowchart format to the macros which tell the computer what to do. The secretaries do from 80 to 95% of the typing and thus the coding, needed for getting the material on the machine. The secretaries quickly become familiar with the effective editing system available on the SIGMA 7, and they use it extensively in correcting the program. If the secretary cannot understand what is happening at a particular place, she types a row of asterisks. The asterisks signal the student programmer who takes the dialog at the next stage, edits it if necessary, assembles it, and tries to run it to see if it accomplishes the desired task. The debugging time is a function of the complexity of the dialog. Simple dialogs, like ELECTRIC, require almost no debugging. However, in complicated multi-branching dialogs, authors loose track of where they are, and much debugging is done by student programmers, who attempt many runs before the program is used for the first time with students.

No matter how much work is initially put into a dialog, that dialog when first used by the class will be in poor condition; it will miss many correct responses, fail to respond to wrong responses that it should respond to, have fuzzy questions, areas where the student is not learning. No one is a good enough teacher to use at first blow all the facilities which are offered to him by this interactive way of teaching.

However when the dialog is used with classes, student responses are selectively stored; this information can be the basis for an order

of magnitude improvement in the dialog. We ask authors to think about how they will use this student feedback while they are writing the dialog, so that they will plan in advance. (Saving student responses occurs only when an explicit SAVE command is used.) Normally authors save responses when they have failed to analyze the student input, as these responses contribute most to improving the program. In some cases the author to save all responses to a question, or not to save the response. A dialog used with large classes generates vast amounts of feedback so background sorting programs to put the response files in a form convenient for the author or student assistants are essential. The rewriting of dialogs on the basis of extensive student use is a vital step to producing viable material.

Who are the authors of dialogs to be? We hope to involve as many competent teaching faculty as possible, but the task is difficult, and perhaps not rewarding given the present academic structure. The question of to use student talents was of major interest to us. We have worked with undergraduate students, working in conjunction with teachers, as dialog writers. Many of our dialogs have had major student contributions. We do not find that all undergraduate students can write such material. It demands an interest in teaching, patience, and tolerance with one's fellow students. But by working carefully with students initially we can identify students who can write successful dialogs. We think that this is a major source of manpower available for this work in the future. Writing of a dialog is also valuable educational experience for the student.

Dissemination Activities

Because we are an active center for the production and use of dialogs in physics, we are often called upon for advice. We have participated in many national meetings concerning computers in teaching, and representatives from the project have talked and given demonstrations in many schools.

Particular attention is being given to the communication of dialogs to others with different computer facilities and environments. Very few current materials are so transferable; we have attempted to find and put such physics materials on our system, but with little success.

We have used the conservation of energy program as a test for documentation and dissemination purposes. Documentation should include the following items for programs to be useful for others.

(1) A paper describing what the program intends to do pedagogically, with examples of usage with students and information about the student group on which the program was tested, should be available.[3]

(2) An flowchart of the program should be available, not showing the details of the individual steps, but outlining the program.

(3) A full flowchart is the single most useful tool in providing access to the program to another facility. We have experimented with different types of flowcharts, and have derived one particularly suited to this purpose. The success of this approach has been shown

by the fact that others have taken this program in flowchart form and established it in very different systems from that for which it was initially written. First it was recoded in FOIL, a FORTRAN-based language at the University of Michigan. More recently it has been transcribed into Hewlett-Packard BASIC by G. W. Rolloson, at Menlo College, Menlo Park, California. Rolloson's experiences were particularly interesting, as he was working with a system not particularly adapted for such dialog material. Starting with no software other than BASIC, and with our flowchart he recoded the dialog in two weeks. This version has also been modified for the Dartmouth BASIC system, and is available there. A new Michigan version also exists, programmed in PIL. So five versions of the dialog exist, on five different computer facilities

(4) The listing of the programs, either as a line printer listing, or as a tape copy, should also be available. In a secretary-oriented language such as ours, the listing is readable and useful in programming It may be possible to use the listing or tape as the basis of the new program, since much of the text material will go unaltered. The group at the University of Michigan that put the energy dialog into PIL (JOSS), used a paper tape copy of our program and the editing system of an IBM 360-67.

One issue involved in the coming widespread use of computer materials in teaching situations is the availability of the necessary computer resources. In cooperation with a group of Northern California community college teachers, particularly Herbert Peckham at Gavilan College, we have estimated, for the administrator, the resources necessary

for the use of computers in physics teaching.[7]

The Physics 5 Course

The Irvine Physics 5 course makes extensive use of computers in the first two quarters of a five quarter course for 200 science and engineering majors, covering mechanics, waves, and relativity. We estimate that each student will spend 1 1/2 terminal hour per week for 20 weeks at the computer terminal, 6,000 terminal hours in all. Approximately half is expected to be computational and about half dialog. Many of the dialogs are receiving extensive testing with students during these two quarters, and we will be provided with large amounts of feedback material for rewriting and improving these programs.

A number of experiments are underway. Our facilities allow us to switch a student to one or the other of several versions of a dialog. It has been conjectured by a consultant, Edward Lambe of the State University of New York at Stony Brook, that dialogs may be very sensitive to changes in technical style. We are using the conservation dialog in two quite different forms, identical in subject matter and content, but using different technical vocabulary. The student will randomly be sent to one or the other versions, and we shall study the response files for differences in student success and types of responses. Similar issues involve the first person versus third person style, and its effect on the student. Most of our dialogs use first person, but some of our friends have objected to this. We will study this stylistic choice, using multiple versions of a dialog.

The Physics 5 course uses many means for teaching physics. Some material can be learned in a number of different ways. We intend to run correlation studies between different aspects of the course, including computer aspects.

We also hope to make a comparitive study of this computer-based course and several "standard" textbook courses. The product would be a graphical mapping of the general subject area of these courses, charting the paths of several texts over this terrain, paying particular attention to the time and mathematical skills each requires to arrive at common points of problem solving ability. This map might develop into a useful device for evaluating the effectiveness of different teaching strategies and materials in particular subject areas. It could prove immediately useful as one aid for course planning. By revealing the position and scope of new dialogs, films, and instructional components, it would both inform and greatly ease the task of charting an effective course in new directions.

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